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# An SDI for the GIS-education at the UGent Geography Department

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## ABSTRACT

The UGent Geography Department (GD) (ca. 200 students; 10 professors) has been teaching GIS since the mid 90's. Ever since, GIS has evolved from Geographic Information Systems, to GIScience, to GIServices; implying that a GIS specialist nowadays has to deal with more than just desktop GIS. Knowledge about the interaction between different components of an SDI (spatial data, technologies, laws and policies, people and standards) is crucial for a graduated Master student. For its GIS education, the GD has until recently been using different sources of datasets, which were stored in a non-centralized system. In conformity with the INSPIRE Directive and the Flemish SDI Decree, the GD aims to set-up its own SDI using free and open source software components, to improve the management, user-friendliness, copyright protection and centralization of datasets and the knowledge of state of the art SDI structure and technology.

The central part of the system is a PostGIS-database in which both staff and students can create and share information stored in a multitude of tables and schemas. A web-based application facilitates upper-level management of the database for administrators and staff members. Exercises in various courses not only focus on accessing and handling data from the SDI through common GIS-applications as QuantumGIS or GRASS, but also aim at familiarizing students with the set-up of widely used SDI-elements as WMS, WFS and WCS services.

The (dis)advantages of the new SDI will be tested in a case study in which the workflow of a typical 'GIS Applications' exercise is elaborated. By solving a problem of optimal location, students interact in various ways with geographic data. A comparison is made between the situation before and after the implementation of the SDI.

## INTRODUCTION

Since the beginning of teaching GIS, the meaning of this acronym has evolved in time from Geographic Information Systems, to GIScience, to GIServices. It is not that GIS is restricted to one of the meanings, but it has become broader. While in the beginning years, a GIS was a computer-based centralized system, it has more and more become an internet or web based decentralized service; the view of a GIS has been evolving from a technologically dominated view to a more science oriented view (Jiang and Yao, 2010). As such, necessary skills for graduated geospatial Master students have evolved in time too. Scholten et al. (2009) mentioned more than 110 different domains that use GI technologies. De Bakker and Toppen (2009) predict that geospatial education will evolve due to a growing diversion of demanded skills resulting in graduated students with different focuses: (i) a user of GI information in a specific domain, (ii) a data manager, (iii) a Geo-ICT expert and (iv) a coordinator.

In 2007, the European Commission ratified the INSPIRE Directive (Infrastructure for Spatial Information in Europe) aiming for the set-up of a European Spatial Data Infrastructure (SDI), based upon components of SDI's at the national and sub-national levels. The INSPIRE Directive should assist policy-making in relation to policies and activities that may have an impact on the environment (European Commission, 2007). This Directive resulted in the Flemish SDI Decree (Flemish Parliament, 2009), with the set-up of the SDI Flanders partnership as one of the most comprehensive initiatives to coordinate and facilitate the exchange of data between all kinds of Flemish organizations (Dessers et al., 2011). Vandenbroucke et al. (2009) give a review of the many definitions of SDI and indicate that almost all definitions are related to their components. That is also the way Steiniger and Hunter (in press) define an SDI, containing the following components: (i) Spatial Data (or spatial information), (ii) Technologies, i.e. hardware and software, (iii) Laws and Policies, (iv) People, i.e.: data providers, service providers, users, and (v) Standards for data acquisition, representation and transfer.

As a lot of SDI aspects are quite technical and complex (e.g. standards of services, metadata and data specifications), a good education is crucial to foresee a smooth transfer of knowledge in the future. This training for working with spatial data can be provided by governmental institutions such as AGIV (Flemish Geographical Information Agency), by companies and by knowledge institutions, such as universities. As geography students are potential future employees that will be involved in the set-up and use of SDI's, geography education at universities should focus more on the different SDI aspects, which until now have been treated in a limited way.

The widespread use of Free and Open Source Software (FOSS) is apparent in the GIS field (Steiniger and Bocher, 2009). The FOSS components are perfectly valid for building an SDI is demonstrated by Steiniger and Hunter (in press).

The aim of this paper is to demonstrate that the set-up of a proper SDI for the GD is an important step towards an adapted GIS education that is conform to the strong evolving needs.

## MATERIAL AND METHODS

Two scenarios have been used for the GD in general, and for the case study of the paper more specifically. In the old scenario, a simple architecture consisted of a desktop GIS with the input datasets stored on a file server (Figure 1a). In the new scenario, a basic SDI was set up, consisting of a spatial database and an application server connected with a desktop GIS (Figure 1b). In the first scenario, ArcGIS has been used, while in the second scenario the FOSS packages PostGIS, GeoServer and QuantumGIS (QGIS) with GRASS plug-in have been used respectively.

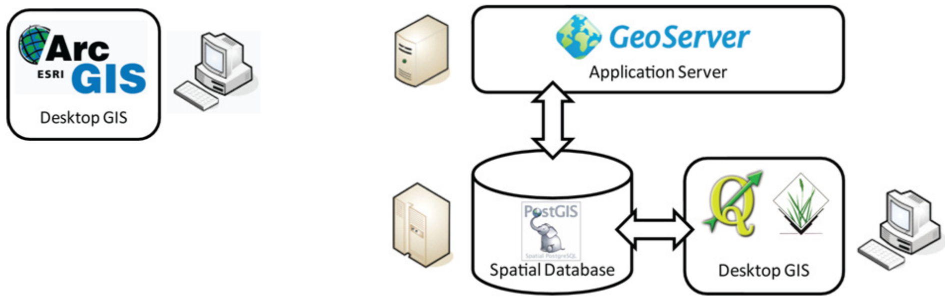


Figure 1a (left): Architecture of the old scenario containing a desktop GIS (ArcGIS) and Figure 1b (right): Architecture of the new scenario with a desktop GIS (QGIS / GRASS GIS), a spatial database

### Old scenario

Until recently, the GD used a classic system for handling data in exercises on a number of fields such as e.g. GIS and digital cartography. Both geographic and non-geographic data were stored on two separate file servers that were subject of a full mirror backup every 24 hours. One of those servers was intended for ‘source data’: staff members had full access and data was organized in a directory structure reflecting the academic year and names of the courses. Students could read all available data on this server regardless of their level or status. The second server held students ‘home folders’: every student got ample storage space and these folders were also accessible for staff members to monitor progress or grade assignments.

Ever since the start of GIS education in the GD, the ESRI line of desktop products has been the principal software used to introduce GIS to students. Ghent University had an agreement for 90 floating licenses available to the whole university (over 30000 students and over 7000 staff members) and the software was available through the central system for application virtualization Athena. This system was rather susceptible to errors and slow working speed and therefore some pc-rooms got local installations of the ESRI desktop products. Using the software from home was only possible through VPN on the error-prone Athena virtualization platform which lead to frequent complaints from students about the limited availability of the pc-rooms.

### New scenario

The GD opted for the implementation of a proper SDI. Central in the system is a PostGIS database which holds the geographic data. This PostGIS database is a PostGreSQL database enhanced with the extension PostGIS for dealing with spatial data in the framework of a SQL database. In this way, it not only enables the classic non-spatial queries and administration, but also certain basic spatial analysis to be computed directly by the database system. For example, calculating a buffer area around a spatial object no longer requires desktop GIS software to load the data, calculate the buffer and store the resulting feature, but can be directly handled by the PostGIS database.

In the spatial database, each layer of information is stored as a new table. These tables can be grouped in a schema which in turn can be combined in a database. One server can hold multiple PostGreSQL databases but since that configuration does not allow queries that use multiple databases, the central database of the SDI has been constructed as a single database in which each user was assigned a single schema. For this schema, the user has full access rights and can allow other users to access the data. This gives students the possibility to cooperate on certain projects without having to deal with exchanging data.

A second range of schemas is created for each course and is fully accessible for the selected staff members and offers read access to students enlisted for that course. A last set of schemas is dedicated to larger sets of base data that are available for all staff members. Students can get access through a procedure in which they state the purpose for which they intend to use the data, the approval of a staff member and the spatial extent of the information they would like to access. After this, they can either get read access to the entire table/schema or get a subset of the data added to their personal schema. To adequately administer this huge database, a web-based management system is being developed. It can be used by the administrator to create new schemas or tables and assign user rights to them. Staff members can use a well-organized webpage to add data for their courses or to grant rights to specific students for specific datasets. For students, a similar webpage allows to administer their own data or to apply for access rights for (subsets of) data and to monitor the amount of free disk space they have available.

Next to this PostGIS implementation, the SDI also includes a GeoServer which is mainly used for providing copyrighted data. Several web mapping services (WMS) were implemented that retrieve data from georeferenced raster imagery, the PostGIS database or a combination of both. Premium example here is the availability of high resolution orthophotos for the entire territory of Flanders.

The introduction of new technology does not stop with the data-providing side of the process. The major application for introducing students to GIS has changed too: QGIS has replaced ESRI's ArcGIS as the first tool students get to work with. Although QGIS lacks quite some of the advanced analysis tools that are available in ArcGIS, the partial switch to FOSS holds a few benefits. First of all, students can freely install and use the software on their own systems and are no longer subject to the limited availability or performance of the software provided by the university. Secondly, as a platform to introduce the basic concepts of GIS, the open source QGIS is very similar to ArcGIS in usability and performance. This does not mean that the position of ESRI as market leader and requirement of knowledge of their products in the industry is no longer acknowledged: after introducing the concepts, students are still required to use ArcGIS to complete certain assignments.

### Case study in the old and new scenario

The case study area of this paper is the Belgian Part of the North Sea (BPNS). In this area a fictive exercise of suitability analysis for the construction of a new windmill park is performed, comparable to a student exercise. The input datasets are real data of the BPNS (for references of the datasets cfr. Table 1): (i) occurrence of users: where a user is located, no new windmill park can be located, (ii) distance to 12 nautical miles: the park may not be too far from the coastline (because of economical costs) and not too close (because of the view), a distance of 12 nautical miles is for this exercise considered as a good compromise (iii) distance to Zeebrugge harbour: the closer to the harbour, the more suitable, because of a possible connection with the existing electricity network (iv) bathymetry: the deeper, the less suitable, (v) geology: clay is the most suitable substrate, followed by sandy clay, clayey sand and the co-occurrence of clay and sand, (vi) bedforms (dune structures): the higher the bedforms, the less suitable. Other datasets such as hydrodynamic conditions, grain size, or biological species are not taken into consideration.

A spatial analysis (consisting of merge, buffer, vector to raster, raster reclassification and distance calculation operations) results into different rasters with suitability classes ranging between 0 (not suitable) and 10 (very suitable). In the last analysis step, weights are assigned to the suitability rasters, which results into a final suitability map showing zones that are suitable or not for a future windmill park (Figure 2).

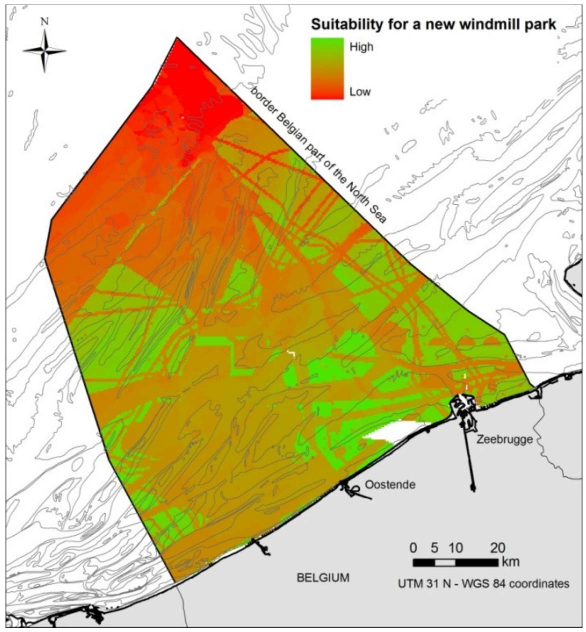


Figure 2: Suitability map for a fictive new windmill park on the Belgian part of the North Sea. The exercise shows that not a lot of suitable locations can be found for new windmill parks. The most suitable locations are situated close to the coast of Oostende and Zeebrugge, in between the user functions. As this is a fictive exercise, the interpretation of the map does not matter for this paper.

Table 1: Datasets that are used as input for the suitability analysis.

| DATASET | REFERENCE |
|---|---|
| **User functions** on the Belgian part of the North Sea (weather masts, radar mast, wrecks, pipelines, telephone cables, Zeebrugge harbour, military exercise zones anchorage area for vessels, dredge disposal areas, aggregate extraction zones, Ramsar and Habitat Directive nature areas, shipping lanes, shipping routes) | GAUFRE project: Maes et al., 2005 |
| **Bedforms** (dune structures) | MAREBASSE project: Van Lancker et al., 2007 |
| **Geology** | Le Bot et al., 2003 |
| Bathymetric data for **digital terrain model** | Flemish Authorities, Agency for Maritime and Coastal Services, Flemish Hydrography |

## RESULTS

### Impacts for staff, students and organization

So far, the introduction of the SDI has had major implications on the way both staff and students organize, prepare, experience and evaluate exercises.

As a starting point, all staff members using geographic data, GIS analysis or digital cartography in any form or to any extent in their courses had to be properly informed about the ins and outs of the new system. This was done in a two-day crash course on open source GIS software and SDI's. In a series of real-life scenarios, all aspects of handling the available geographic data were covered: from creating course specific data subsets, over combining locally stored data with publicly available data, to integration of web based services. Because the launch of the SDI was combined with a switch to open source QGIS as principal desktop GIS application, all of this was linked with an introduction to QGIS that closely resembles the introductory exercises on GIS that students get. In this way not only the new platform could be tested, but also the renewed educational approach was evaluated by some highly critical colleagues.

Although the need for staff members to adapt to the new system and bring the geomatics skills of people from other fields (social geography e.g.) to a 'higher' level was initially listed as a drawback for implementing the new system, most people in the GD agree that it has increased flexibility. In order to also increase ease of use for staff members, a number of scripts are being developed that will allow them to perform certain routine tasks through a web-based interface. Thus, they do not have to worry about specific database implementations and can make data available for certain (sub)groups of students as in the old system.

The second step was a complete overhaul of the way to give students hands-on experience in working with GIS software. With more and larger datasets easily available, preference was given to learning methods that ask more initiative from the individual student. Rather than providing students with data carefully prepared for a certain exercise, the new system allows tutors to point students in the right direction and let them build their own personal repository. The first advantage for students is the introduction to innovative technology. For example, already in series of basic GIS exercises they learn how to use an SDI which is fundamentally different from working with some files on a local hard drive. And in more advanced courses, they are introduced to the tasks of an SDI administrator and developer. A second major advantage is of course the access for all students: instead of working with outdated local copies of certain data layers, they can now at any time access the latest available data.

From a more organizational and technical point of view, the SDI has a clear impact on the IT organization of the department. First of all the system had to be installed, configured and thoroughly tested by someone who is familiar both with the technical aspects of servers and databases, and with the particularities of geographic data. This meant that although the IT section of the department provided hardware with operating system and reliable backup facilities, configuring all other aspects had to be done by a member of the teaching staff. This certainly had its influence on the availability of that person for other courses and activities. But it does not stop there, once the system is up and running, this person still has to dedicate a significant amount of time to administer it. These tasks involve e.g. user administration, adding and updating new geographic data, administer services (WMS, and web feature services (WFS), and provide advanced user support for staff members. Moreover, from the organizational point of view, the system allows more flexibility: the use of certain data can be restricted to certain groups and therefore data-suppliers are clearly persuaded to provide some more sensitive real-life data.

### Case study compared in two scenarios

As this exercise has been performed by one single person on a desktop, the difference between the two scenarios is not significant, but in the case of a large user group, e.g. different student groups from different GIS courses, working on this exercise, the advantages of the second scenario would tend to become more effective. In Table 2 pros and contras of the scenarios are listed. The more users and the more datasets, the more positive effect of the second scenario.

Table 2: Advantages and disadvantages of the old and new scenario

| | Old scenario | New scenario |
|---|---|---|
| Advantages | - number of ArcGIS functionalities is very extensive, both concerning raster and vector operations<br>- the overall performance of ArcGIS is still better than open source desktop GIS software<br>- most effective for simple exercises with a small number of datasets and a small user group | - number of QGIS / GRASS functionalities is continuously increasing and improving because of large and very vivid user and developer community<br>- very effective for a large number of datasets and users<br>- data are stored on a central server<br>- compatible with OGC services<br>- free and open source components |
| Disadvantages | - datasets are copied and saved countless times<br>- not compatible with all OGC services<br>- expensive | - the current version of PostGIS is not able to deal with raster datasets<br>- technical knowledge of teachers / assistants is necessary for the set-up / maintenance of a PostGIS database and a GeoServer application server |

## DISCUSSION

### Setting up an SDI in the context of GIS education

As the INSPIRE Directive aims for the set-up of a European SDI, the implementation of this Directive and the Flemish SDI Decree will happen based on a phased approach with an inventarisation of geographic datasets, an adaption of the ICT infrastructures, an adaption of the metadata, a harmonization of datasets, making the datasets available and an adaption of management processes. All of these steps will happen between 2011 and 2019 (AGIV, 2010). This planning will require a lot of effort, where all of the four professional aspects that were defined by De Bakker and Toppen (2009) play a crucial role. The user of GI information will have at the end of the process well-structured data and metadata conform to the INSPIRE standards. The data manager will have a very important role in the inventarisation, harmonization and delivery of datasets. The Geo-ICT expert will have the main responsibility in setting up the technical part of the SDI, that will be used by all stakeholders, data users, data managers and coordinators. The coordinator has to manage the whole process and needs a broad knowledge on all aspects, a high level education is necessary. Possibly not all graduated GIS students need a knowledge that covers all of these aspects at the same level, but at least they have to be familiar with terminologies and basic GIS and ICT skills. Using and managing data are basic skills for a GIS expert, while Geo-ICT and management is more specific and can be considered as optional specialization. A Geo-ICT expert will need more specific ICT skills such as programming, while a coordinator will need knowledge on management processes.

The relevance of implementing an SDI for the GD or Ghent University is twofold. The first point was already mentioned above: industry expects graduated students to have a certain level of knowledge on the components of an SDI and although there is no intention to make them all SDI-administrators, active use of a fully functional SDI will prepare them better for a range of jobs after graduation. Secondly, its relevance is demonstrated by the elements referred to in the results section of this paper: for students and staff and from an organizational point of view, the introduction has proved quite beneficial for all those involved. But of course, as with every new route that is taken, some unforeseen bumps on the road have to be dealt with.

### Technology

That FOSS is a hot topic in the GIS world, is proved by the success of the yearly FOSS4G (FOSS For Geospatial Conference) Conferences, that in September 2011 in Denver was attended by over 900 participants.

Although it is possible to set up an SDI based on ESRI or other non-FOSS components, the GD has made a very definite choice to build its SDI based on FOSS components. The reason for this choice is threefold: (i) no license costs have to be paid by the Department or the University, (ii) as stated before, students can freely install and use the software on their own pc's, (iii) an SDI with FOSS components supports open formats.

The two scenarios from the case study made use of different software packages (ArcGIS versus QGIS / GRASS / PostGIS / GeoServer). From own experience, it is still easier and more functional to use ArcGIS than QGIS to create a high quality map and lay-outs. Sillero and Tarroso (2010) compared the number of functionalities between different GIS software packages. At the moment of their publication, ArcGIS counted 114 functionalities, QGIS 94 and GRASS GIS 84. Still, the development and use of FOSS is boosting enormously over the past few years. This boost is proven by four indicators in Steiniger and Bocher (2009); (i) the number of recent started FOSS projects, (ii) the increasing financial support from governmental institutions, (iii) the increasing download rates of FOSS software and (iv) the increasing number of use cases. Students often have the perception that a GIS is only a desktop software to create beautiful maps. However, they should be aware of the magnitude and importance of a GIS and in particular an SDI with all its components.

### Future perspectives

Good GIS education results in highly qualified graduated students that are ready for the job market. As this job market is continuously evolving and as this market is becoming broader, it is our aim to organise in the near future a large scale inquiry in Flanders. Different GIS related job market stakeholders from private companies and governmental institutions will be questioned about particular needs and skills. Current education focuses a lot on data use and data management, while Geo-ICT and project coordination are important skills as well, as stated by De Bakker and Toppen (2009).

So far, there has been no evaluation of how the new system influences the learning process of students. Although it is not easy to quantify this influence, it is an essential element of improving and diversify the ways in which students can gather knowledge about GIS and SDI's. Moreover, at the end of this academic year, a questionnaire will be distributed in which students will be asked to evaluate several aspects of using the SDI and how the system and its integration in the study process can be improved. This should allow to not only focus on intended goals and results, but also to take into account some of the unforeseen issues students will probably encounter.

Regarding the understanding of students' cognitive processes from learning experiences with GIS, Baker and Bednarz (2003) stressed the need of more substantive research on this topic. This is indeed crucial for a better understanding on how certain adaptations in educational strategies and methodologies are perceived by students. DeMers (2009) cooperated at the UCGIS Body of Knowledge, a recommended baseline for the GIS and Technology undergraduate curriculum. He suggested that there is a need to increase the number of GIS learning objectives, requiring analysis, synthesis and evaluation. Moreover, higher cognitive level objectives should be included in existing learning objectives, as e.g. defined in ECTS (European Credit Transfer and Accumulation System) documents. It is clear that more research is needed in this domain. Part of the future work will focus on the perception and comprehension of students of study materials. Research questions that can be asked in this context are: how does the set-up of an SDI contribute to the knowledge and understanding of a GIS student? Which learning objectives reach higher levels making use of an SDI?

At the moment, the SDI of the GD is in a preliminary stage. Although it contains an application server (GeoServer), a spatial database (PostGIS) and a desktop GIS (QGIS / GRASS GIS), there are plans to expand the system once the first elements are fully functional and run smoothly. An important element in this extension will be to create a system to manage metadata: both for adding the metadata attached by data-providers as for adding metadata to newly created or changed layers of information. Second aspect is the integration of raster data in the system: the update to PostGIS 2.0 (expected Fall 2011) promises to encompass the storage of raster data. Another point of attention is the development of a virtual platform on which students can learn how to implement their own SDI and manage web services or administer geospatial databases.

Next to these technological steps, the educational method is also under development. A series of instruction videos is being developed and made available online to offer students a more flexible and efficient learning path.

Apart from the extension within the activities of the GD, a broader look to the whole of Ghent University and even cooperation with other institutions of the Association UGent is under consideration. Should the Department try to be the single point of contact for providers of geographic data or should it serve as a testbed for other departments that can build similar architectures and can learn from the experience at the Department?

## CONCLUSION

This paper showed the relevance of setting-up of SDI for the GD as an important step in the direction of an improved GIS-education that is conform to the evolving needs. Since the SDI is in a preliminary phase, it is too early to draw conclusions about the effects of the SDI on better positions for graduated students on the job market or about effects on the work load of the teaching staff. But as the SDI exceeds the level of a desktop GIS by adding a spatial database and an application server, it is foreseen that the effects will be positive for students and teaching staff for different reasons.

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